Environmental and Agronomic Benefits of Enhanced Efficiency Nitrogen Fertilizers

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2020 Soils & Crops Workshop

Why Nitrogen?

- After water, N is the most limiting factor in crop production in Prairie Canada
  - therefore, it is the nutrient applied in the greatest amount
- Crop use of applied N is generally <100%
  - in western Canada, NUE is *ca*. 50% for cereal crops
  - for oilseed crops, NUE is generally considered to be “poor” (*ca*. 30–40%)
- NUE tends to decrease as the amount of N applied increases

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Why Nitrogen?

- Sustainability is now part of the marketing landscape
  - driven by consumer demand for “green” products
- Carbon (C) footprinting is an important component of any sustainability initiative
  - demand for carbon emissions labeling
  - requires emissions accounting throughout the supply chain
- For field crops (and agri-food products in general) nitrous oxide (N_2O) is an important component of the C footprint

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Why Nitrogen?

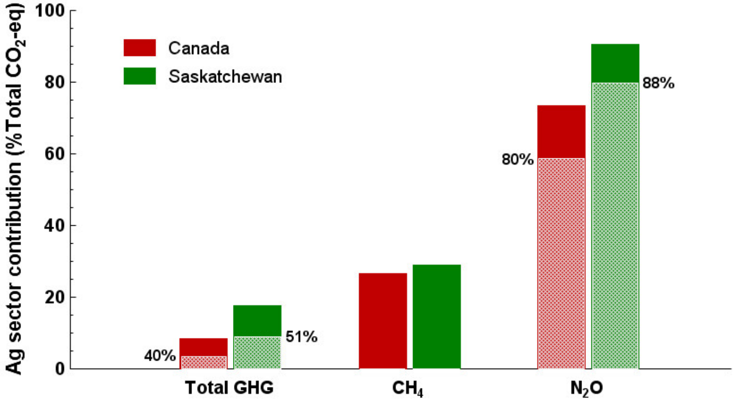
Agriculturally important greenhouse gases

- carbon dioxide (CO_2); GWP* = 1 (t_r = 5-200 yr)
- methane (CH_4); GWP = 25 (t_r = *ca*. 12 yr)
- nitrous oxide (N_2O); GWP = 298 (t_r = *ca*. 114 yr)

*Global Warming Potential: a measure of the ability of each greenhouse gas to trap heat in the atmosphere relative to an equivalent mass of CO_2 (over a specified time period).

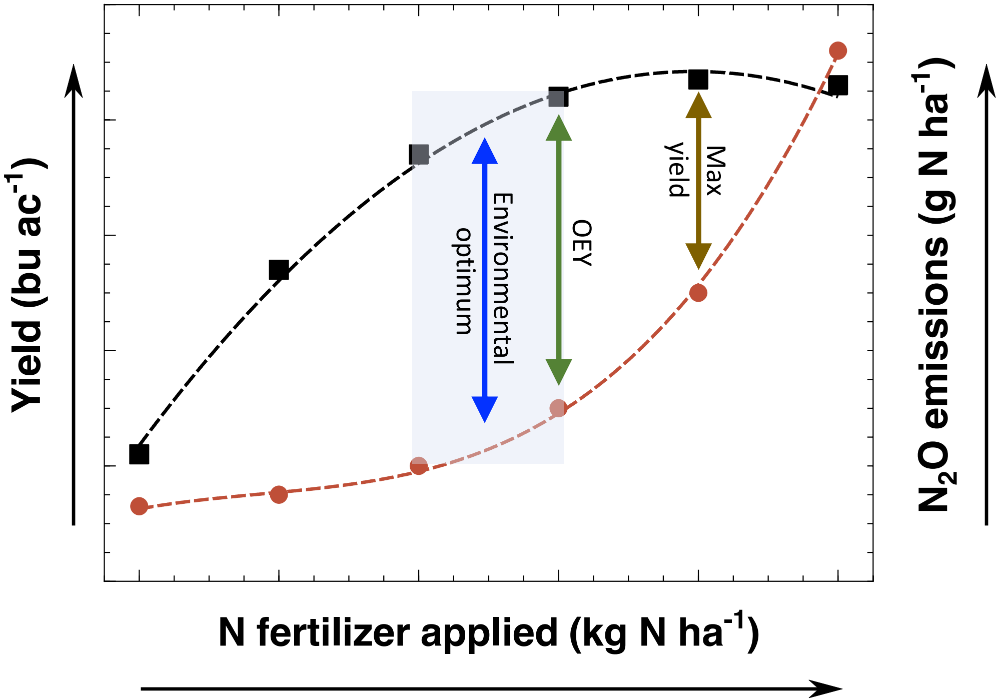
How do we manage N to achieve N_2O emission reductions?

Are agronomic and environmental goals at odds?



N response curves

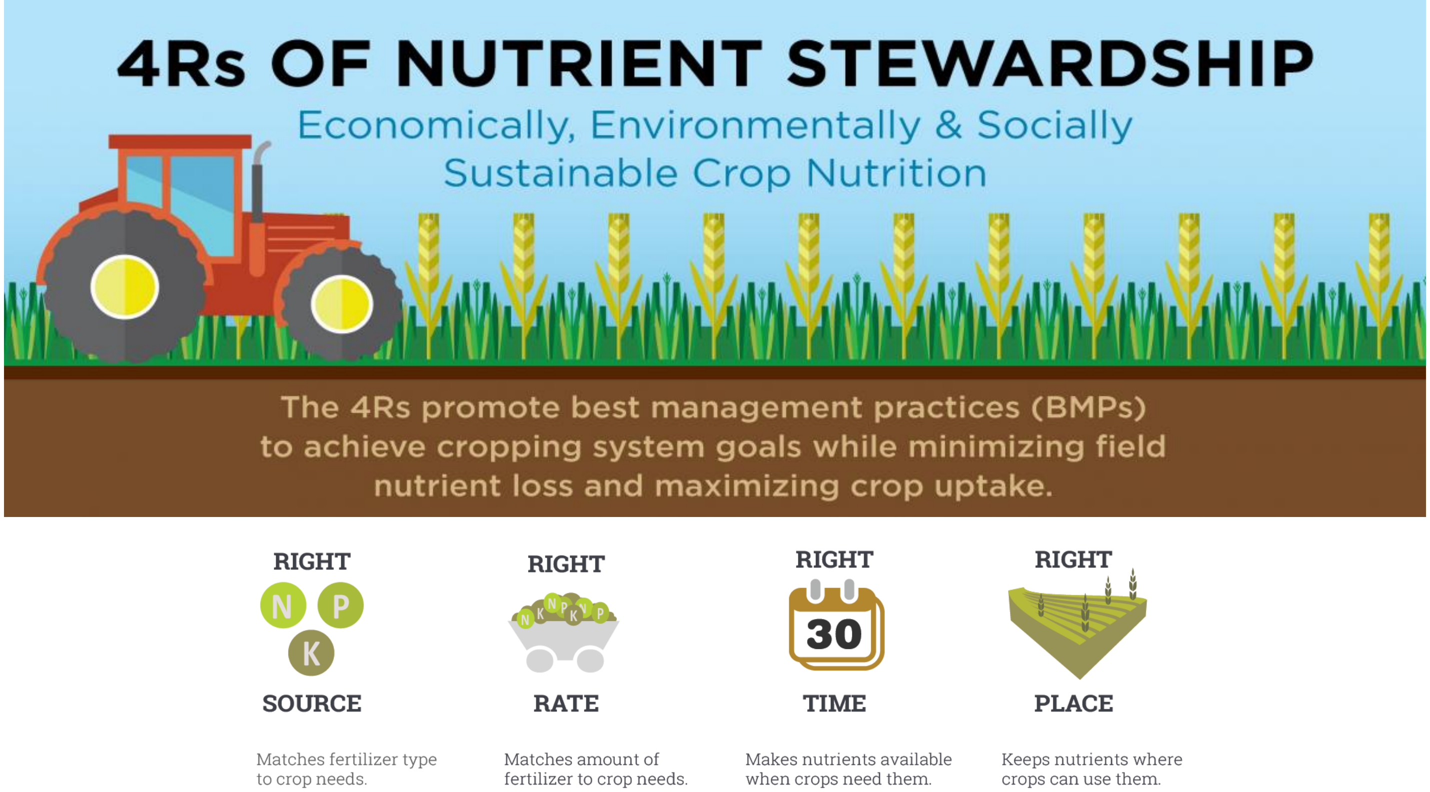
(conceptual model)



What do we do?

- Goal is to improve both the agronomic and environmental performance of cropping systems by increasing NUE
- Synchronize N availability to crop demand
  - nutrient requirements lower in early plant stages
  - sufficient N required *ca*. 2-3 weeks after emergence
- Research has shown that the adoption of BMPs can improve NUE by 10 to 20%
  - apply 4R nutrient stewardship principles

4R Nutrient Stewardship



http://www.nutrientstewardship.com/4rs

Enhanced Efficiency Fertilizers

- ***Enhanced efficiency fertilizers (EEF)*** are products that control the release of N, or alter reactions in the soil that lead to the formation of nitrate (NO_3^-)
    - physically slow the dissolution and release of urea by encasing the granule in a polymer or sulfur coating
    - alter the chemical formulation of the N source to decrease its solubility and slow entry into the N cycle (e.g., methylene urea, urea formaldehyde, isobutylidene diurea)
    - temporarily block microbial or enzymatic processes involved in the conversion of urea to ammonium (NH_4^+) or NH_4^+ to nitrate (NO_3^-)

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Enhanced Efficiency Fertilizers

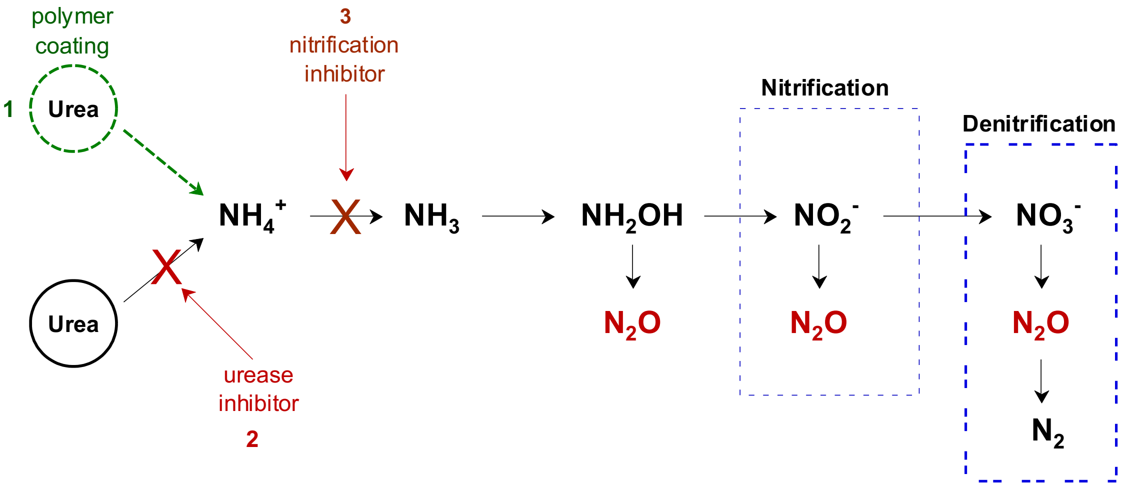
- ***Slow- and controlled release fertilizers***
  - granular fertilizers encased in a coating (sulfur or polymer) that reduces the diffusion rate of the fertilizer from the granule
    - **sulfur-coated urea (SCU)**: the sulfur coating breaks down allowing the granule to slowly dissolve and diffuse out into the soil
    - **polymer-coated urea (PCU)**: a permeable coating that allows water to diffuse into the granule, creating a urea solution that diffuses through the membrane at a rate controlled by the polymer chemistry, thickness of the coating, and <u>soil temperature</u>

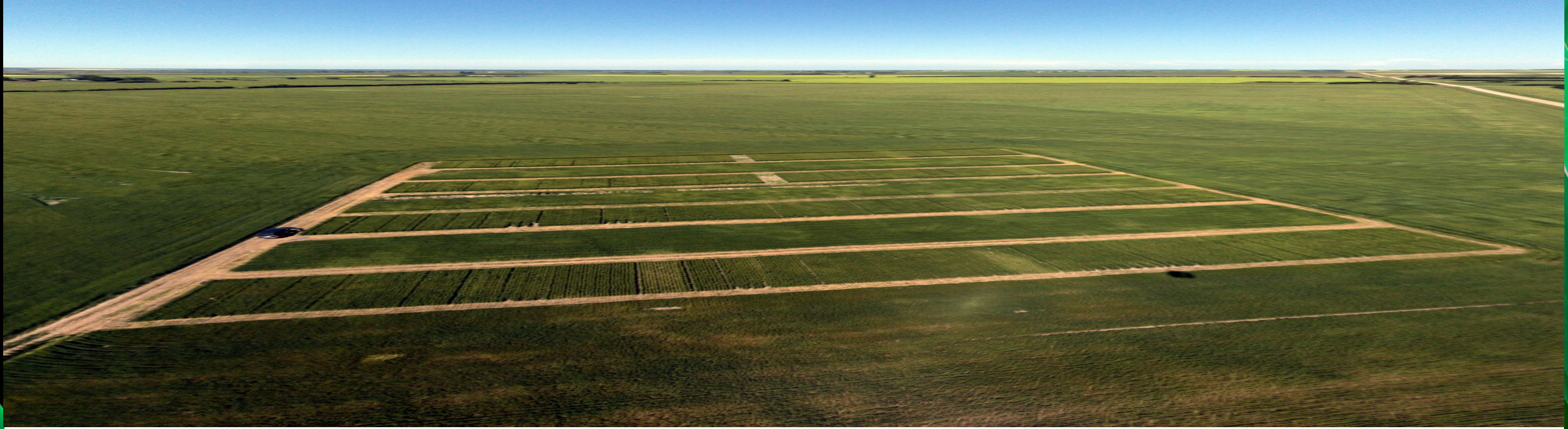
- ***Stabilized fertilizers***
    - **urease inhibitors**: prevent or delay the hydrolysis of urea to ammoniacal N by inhibiting the activity of the urease enzyme
    - **nitrification inhibitors**: inhibit the activity of ammonia-oxidizing bacteria (*Nitrosomonas*) thereby delaying the oxidation of NH_4^+ to NO_3^-

How do they work?

Modes of action

1) polymer (or sulfur) coating to control (slow) release rate of urea;
2) urease inhibitors (UI) to block urea hydrolysis;
3) nitrification inhibitors (NI) to delay the sequential oxidation of ammonium (NH_4^+) to nitrate (NO_3^-).





Use of enhanced efficiency nitrogen fertilizers to reduce N_2O emissions during wheat production

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EENF Products

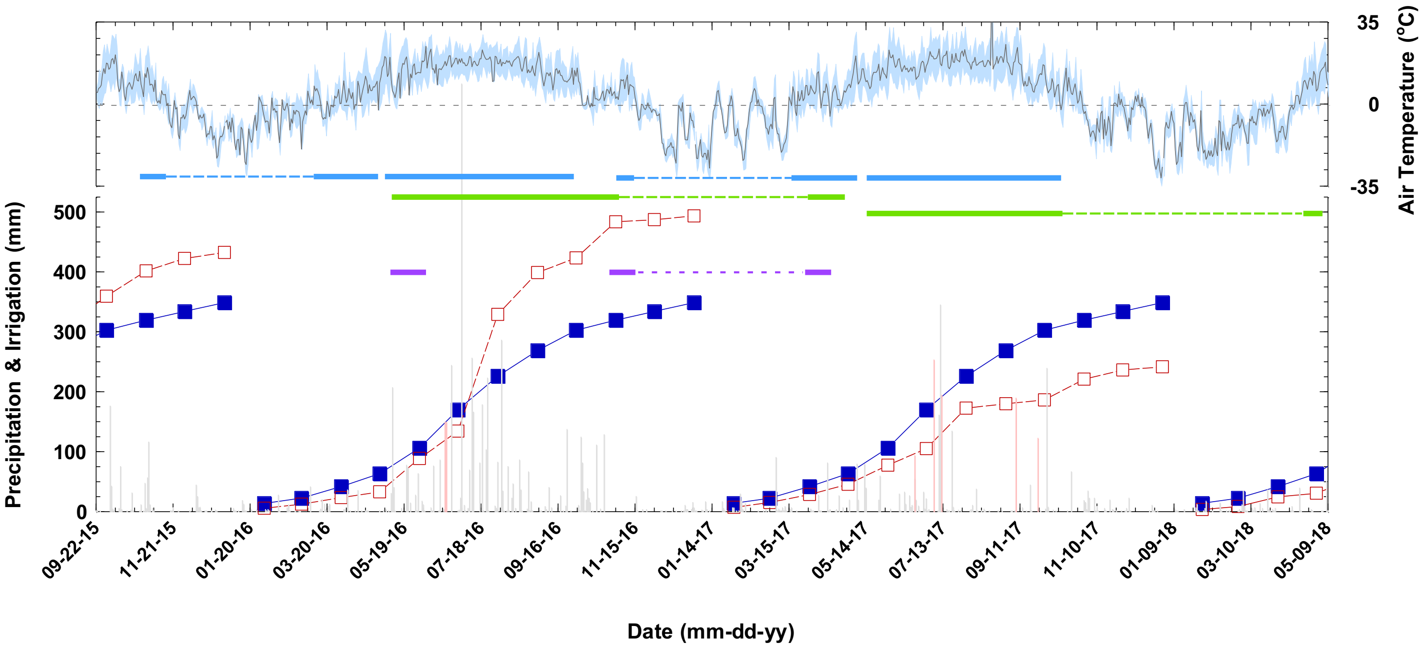
N source	Mode of Action	ai†	ID	EENF	Manufacturer
Urea	Controlled release	Polymer coating	PCU	ESN®	Nutrien‡
Urea	Dual-action urease inhibitors	NBPT & NPPT	DUI	Limus®	BASF
Urea	Nitrification inhibitor	Nitrapyrin	NI	eNtrench™	Corteva Agriscience§
Urea	Urease + nitrification inhibitor	NBPT & DCD	UNI	SuperU™	Koch Agronomic Services
AA	Nitrification inhibitor	Nitrapyrin	NI	N-Serve™	Corteva Agriscience

† Active ingredient: NBPT = *N*-(butyl) thiophosphoric acid triamide; NPPT = *N*-(propyl) thiophosphoric triamide; DCD = dicyandiamide.

‡ Formed when Agrium Inc. merged with PotashCorp of Saskatchewan (formerly Agrium).

§ Formed when Dow Chemical merged with DuPont Chemical (formerly Dow AgroSciences).

Climate data (Fall 2015 – Spring 2018)



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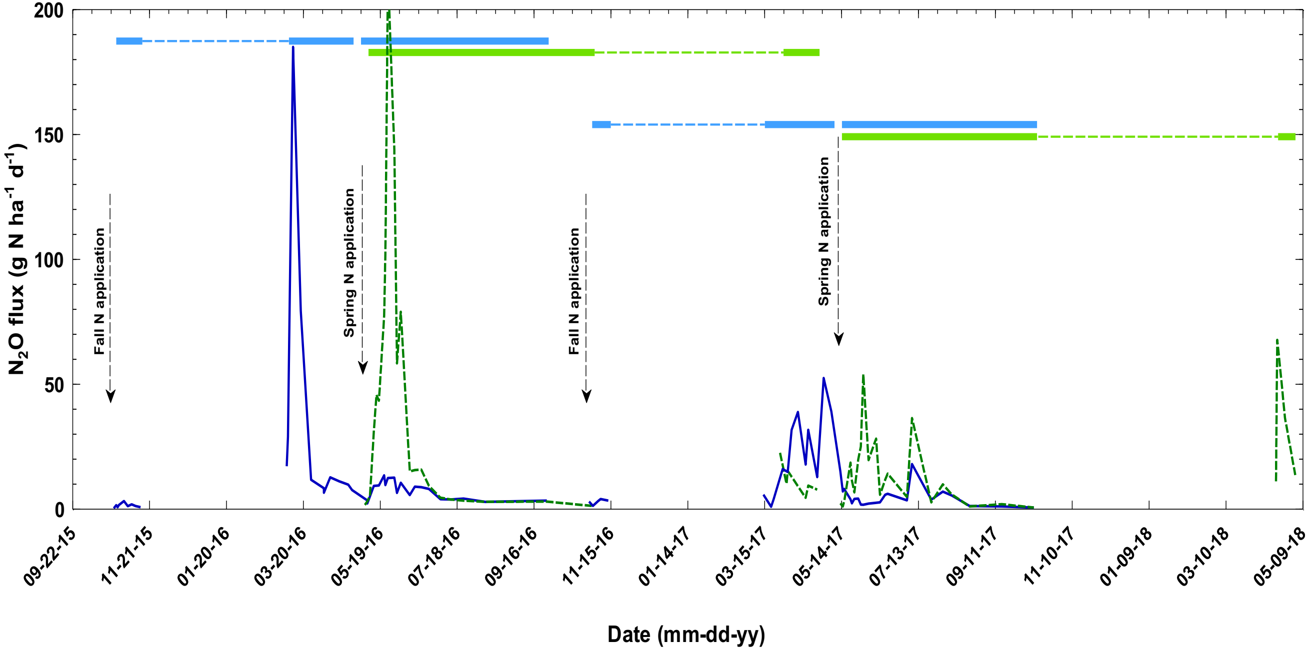
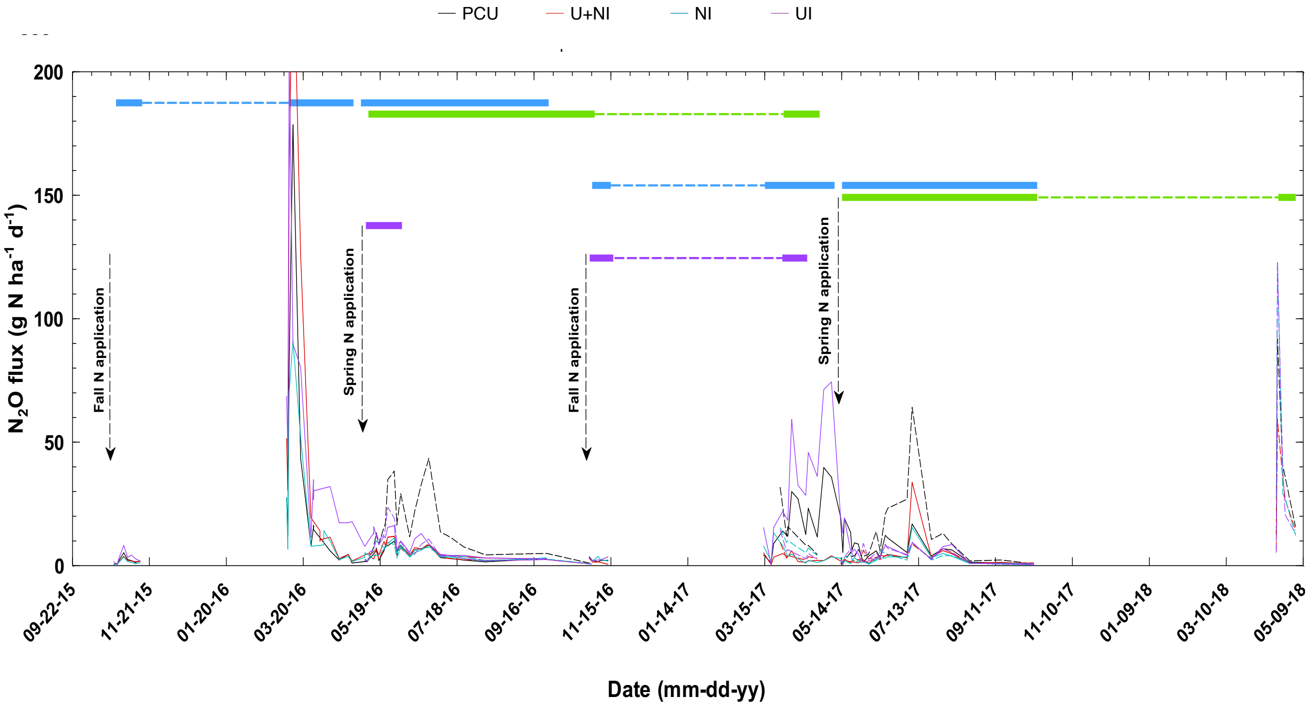
Urea-derived N_2O



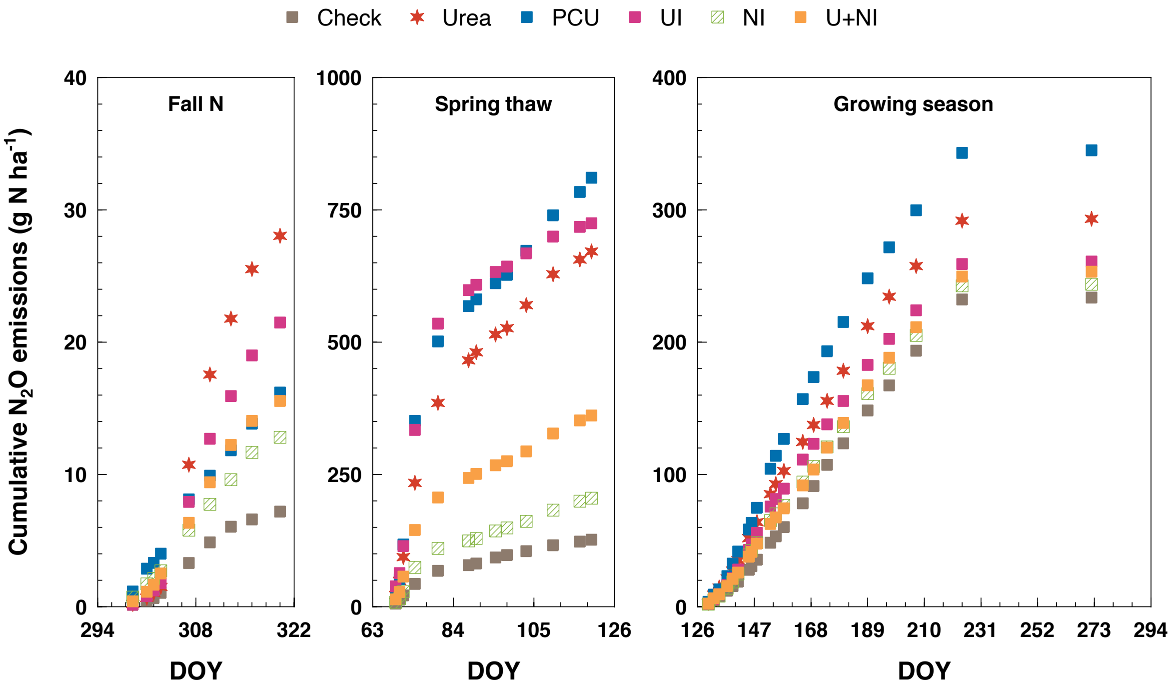
EEF-derived N_2O



Fall applied N

2015/2016

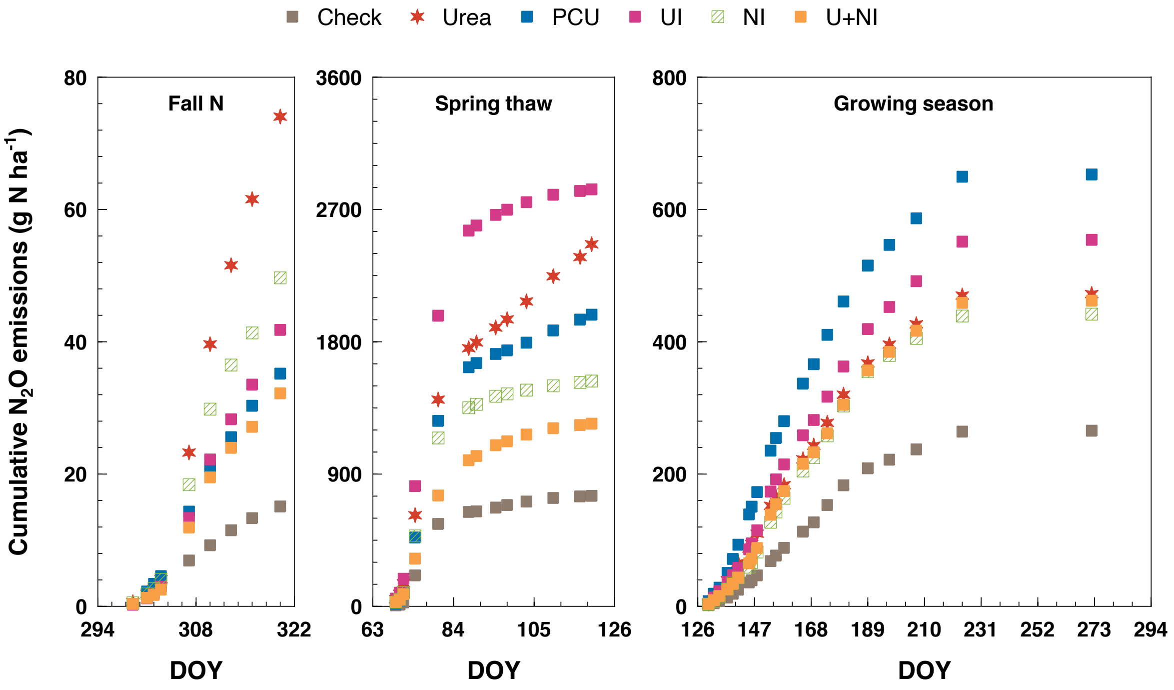
(rainfed cropping)



Fall applied N

2015/2016

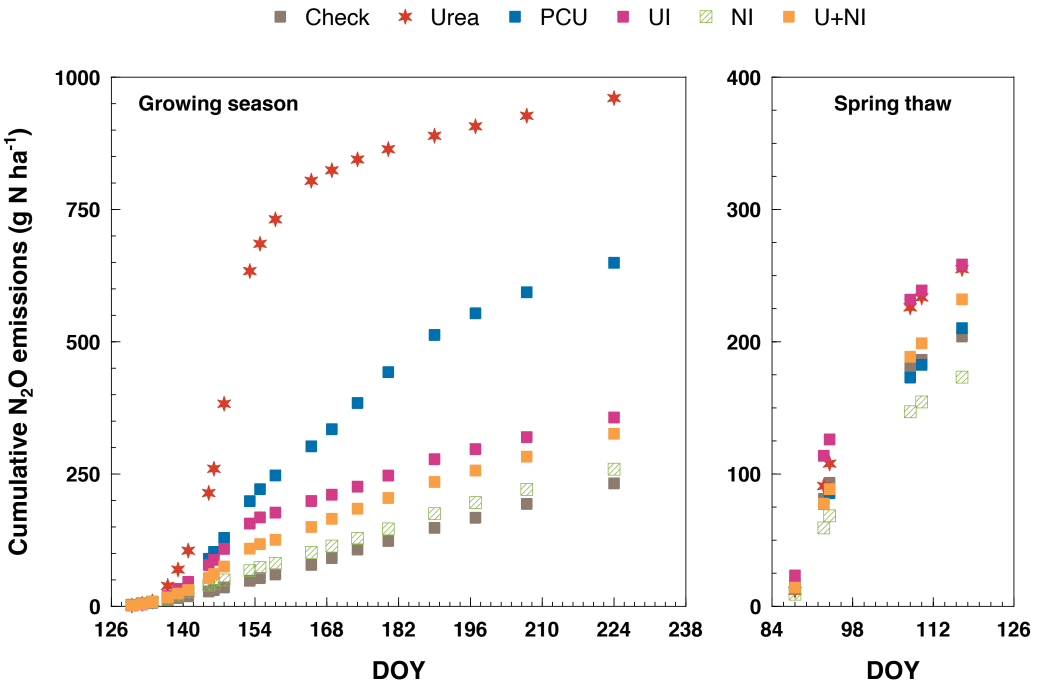
(irrigated cropping)



Spring applied N

2016/2017

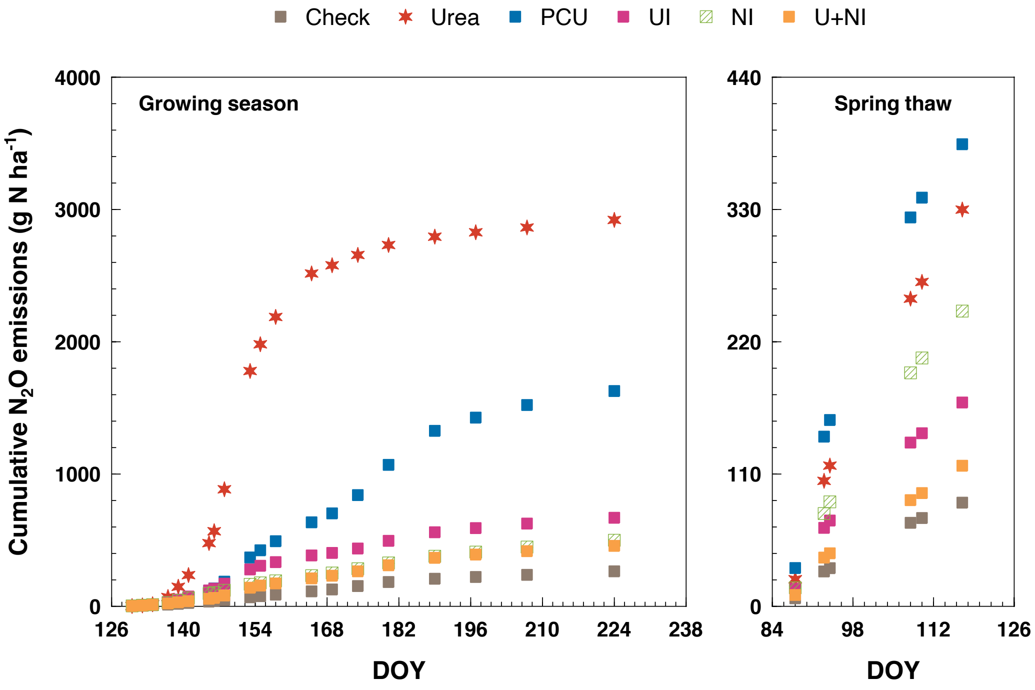
(rainfed cropping)



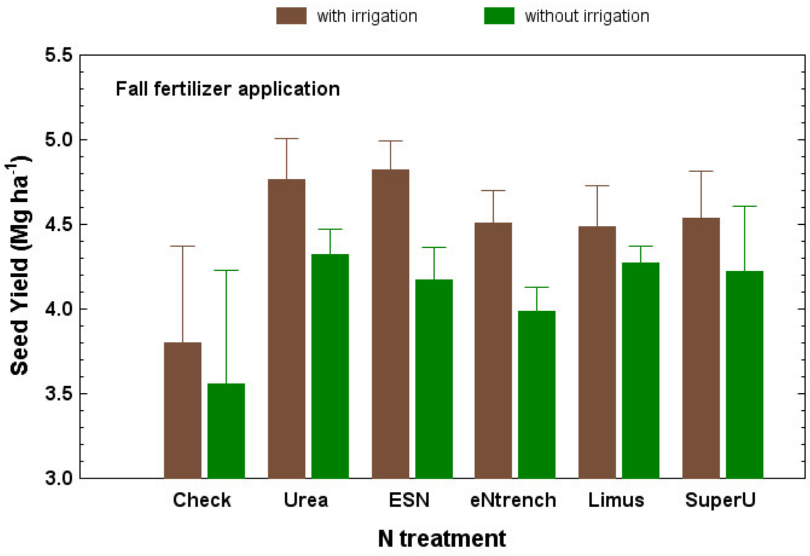
Spring applied N

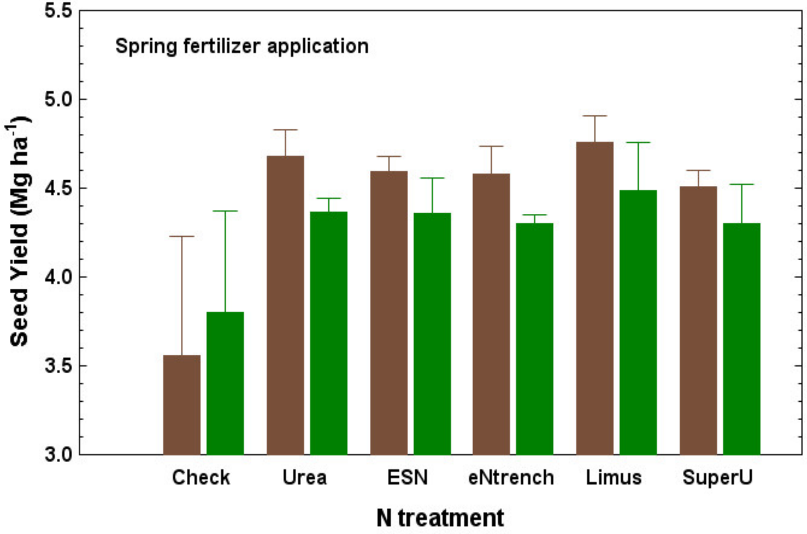
2016/2017

(irrigated cropping)



Wheat yield (2016)





Emissions summary

N source	EEF product	t-N_2O [a b] (kg N ha^{-1})	FIE [c] (kg N ha^{-1})	EF [c] (%)	YSE [c] (kg N Mg^{-1} grain)	t-N_2O [a b] (kg N ha^{-1})	FIE [c] (kg N ha^{-1})	EF [c] (%)	YSE [c] (kg N Mg^{-1} grain)
		------------ Fall-applied fertilizer products ------------							
		-------- 2015-16 --------				-------- 2016-17 --------			
Check (0N)	- - -	1.03 c	–––	–––	0.31 c	0.53 b	–––	–––	0.12 c
Urea	- - -	3.01 a	1.98 ab	1.60 ab	0.72 ab	1.95 a	1.42 a	1.44 a	0.33 b
Urea	PCU	2.67 ab	1.64 ab	1.32 ab	0.64 abc	1.91 a	1.38 a	1.41 a	0.33 b
Urea	UI	3.43 a	2.40 a	1.95 a	0.89 a	2.67 a	2.14 a	2.18 a	0.49 a
Urea	NI	2.02 bc	0.99 b	0.82 b	0.52 bc	0.73 b	0.20 b	0.20 b	0.13 c
Urea	U+NI	1.74 bc	0.70 b	0.60 b	0.44 bc	0.86 b	0.32 b	0.33 b	0.15 c
		------------ Spring-applied fertilizer products ------------							
		-------- 2016-17 --------				-------- 2017-18 --------			
Check (0N)	- - -	0.35 c	–––	–––	0.11 c	0.90 b	–––	–––	0.20 c
Urea	- - -	3.26 a	2.91 a	2.38 a	0.81 a	1.98 a	1.08 a	1.11 a	0.33 b
Urea	PCU	2.02 b	1.66 b	1.35 b	0.51 b	2.35 a	1.45 a	1.48 a	0.44 a
Urea	UI	0.84 c	0.49 c	0.38 c	0.20 c	1.14 b	0.24 b	0.25 b	0.19 c
Urea	NI	0.75 c	0.40 c	0.32 c	0.19 c	1.01 b	0.12 b	0.12 b	0.19 c
Urea	U+NI	0.58 c	0.22 c	0.18 c	0.15 c	0.91 b	0.02 b	0.02 b	0.15 c

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Lessons learned

- Significant N_2O emissions reductions can be achieved in both rainfed (non-irrigated) and irrigated cropping systems by using a urea-based EENF
  - largest, and most consistent, emissions reductions were achieved using stabilized N products that employ a nitrification inhibitor
  - product that employed a urease inhibitor alone yielded significant emissions reductions, but only when applied in the spring
  - polymer-coated urea was the least effective at reducing N_2O emissions, though significant emissions reductions were observed with ESN following the spring application in 2016
    - emissions reductions at both the rainfed and irrigated sites, which suggests that this was not a “random” effect

Lessons learned

- Regardless of absolute magnitude, N_2O emissions reductions were greatest when the EENFs were applied in the spring
- Despite clear environmental benefits of using the EENFs, we were unable to detect any significant agronomic (i.e., yield) benefits
    - likely due to the fact that the N rates applied to the plots were based on soil test recommendations and were chosen to approximate crop demand
    - a small increase in N supply to the crop as a result of a decrease in N loss is unlikely to produce a significant increase in yield, and may only result in “luxury uptake” of N by the crop

Conclusions

- Fall application should not be recommended in the prairies provinces for agronomic and environmental reasons
- Enhanced efficiency fertilizers can be used to reduce N_2O emissions from cropland while maintaining or improving crop productivity
- Including N-serve did not show any benefit over anhydrous ammonia alone on agronomy or reduction of N_2O emissions
  - suggesting a limited benefit to using inhibitors with AA to reduce N_2O emissions
- Environmental and agronomic outcomes are aligned
  - farmers may benefit from voluntarily implementing 4R practices to reduce N_2O emissions through a carbon offset marker

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Western Grains Research Foundation

IPNI International Plant Nutrition Institute

Emissions Reduction Alberta

PAMI

BASF The Chemical Company

Agrium

Dow

Koch Industries Inc

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